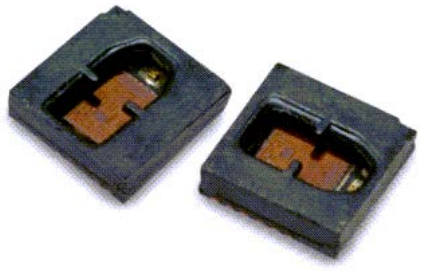
BROADCOM®

Data Sheet

AEDR-9830E

Three-Channel Reflective Incremental Encoders with Analog and Digital Output (318 LPI)



Description

The Broadcom® AEDR-9830E is a three-channel reflective optical encoder. It can be configured to analog or digital outputs employing reflective technology for motion control purposes. The selectable options are two-channel differential analog with a third channel differential digital or analog index output, or three-channel digital differential A, B, and I output.

The AEDR-9830E in analog encoder mode offers two-channel differential analog outputs (Sin, /Sin, Cos, /Cos) and can be interfaced directly with available external interpolators.

The AEDR-9830E in digital encoder mode offers two-channel (AB) quadrature digital outputs and a third channel digital index output. Being TTL compatible, the outputs of the AEDR-9830E encoder can be interfaced with most signal processing circuitries. Therefore, the encoder provides easy integration and flexible design into existing systems.

The AEDR-9830E encoder is designed to operate over a –40°C to 115°C temperature range, and it is suitable for commercial, industrial, and automotive end applications.

The encoder houses an infrared LED light source and photodetecting circuitry in a single package. The small size of 4.00 mm (L) × 4.00 mm (W) × 1.05 mm (H) allows it to be used in a wide range of miniature commercial applications where size and space are primary concerns.

Features

- Analog output option: two-channel differential analog output and differential digital or analog index output
- Digital output option: three-channel differential or TTL compatible; two-channel quadrature (AB) digital outputs for direction sensing and a third digital Index channel
- Built-in interpolator for 1X, 2X, 4X, 8X, 16X, and 32X interpolation
- Surface-mount leadless package: 4.0 mm (L) × 4.0 mm (W) × 1.05 mm (H)
- Operating voltage of 3.3V and 5.0V supply
- Built-in LED current regulation
- Wide operating temperature range: –40°C to 115°C
- High encoding resolution: 318 LPI (lines per inch) or 12.52 LPmm (lines per mm)
- Enhanced compatibility with a wider range of code wheel and code strip material
- Operating frequency from 200 kHz up to 4 MHz (high interpolation)

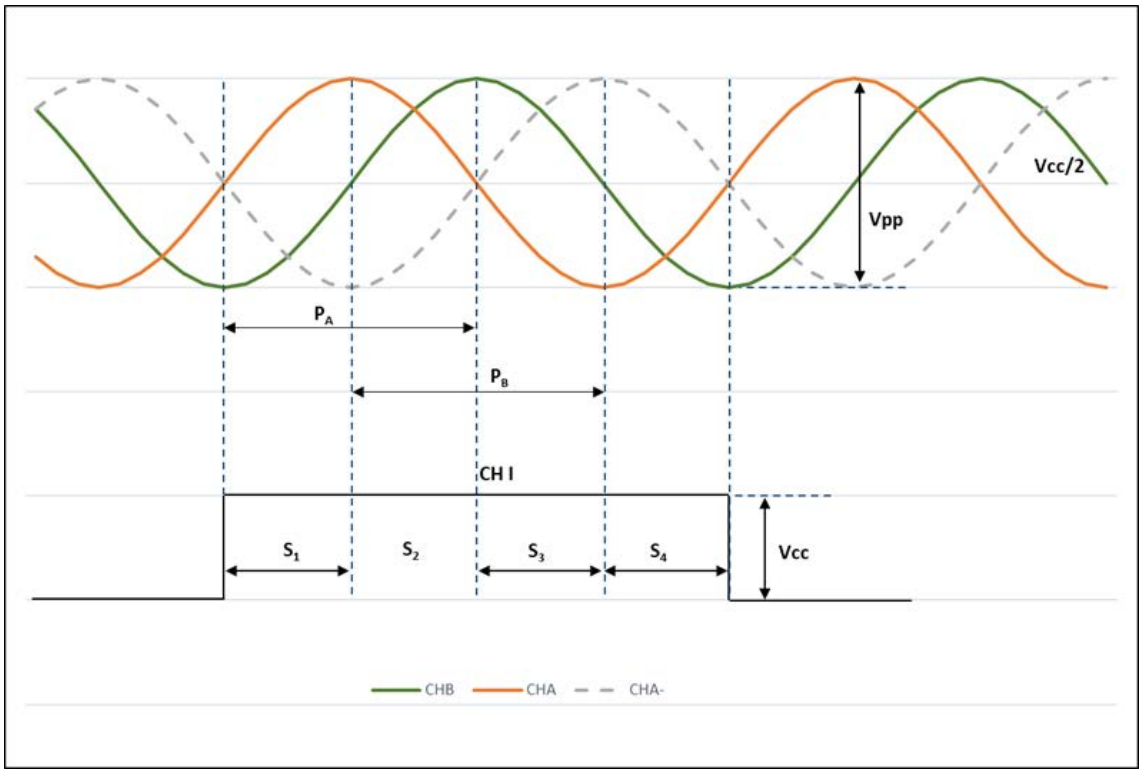
Applications

- Closed-loop stepper and small motors
- Industrial printers
- Robotics
- Pan-tilt-zoom cameras
- Portable medical equipment
- Optometric equipment
- Actuators and linear stages

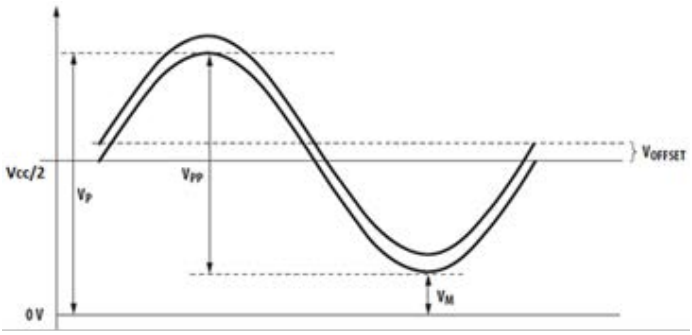
Disclaimer: Except as expressly indicated in writing, this product is not designed or warranted to be suitable for use in safety-related applications where its failure or malfunction can reasonably be expected to result in injury, death, or severe equipment damage. Customers are solely responsible for determining the suitability of this product for its intended application and solely liable for all loss, damage, expense, or liability in connection with such use.

Output Waveform

Figure 1: Analog Output Option – Analog Signals with Digital Index Output



Code Wheel Rotation Movement (Counterclockwise)

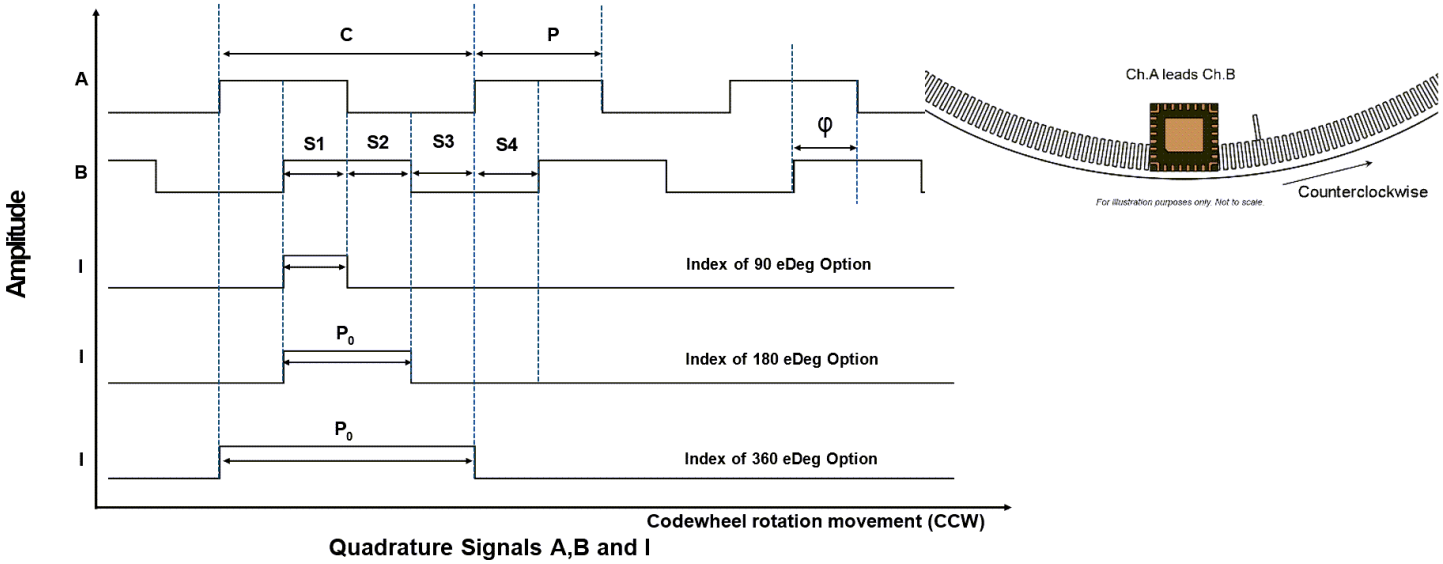


Analog Parameter Definitions

Term	Symbol	Definition
Analog Peak-to-Peak	V_{pp}	The peak-to-peak signal magnitude in V of the analog signal.
Analog Offset	V_{OFFSET}	The offset in mV from the midpoint of the analog peak-to-peak signal to the zero voltage point.
Analog Peak/Valley Voltage	V_{PA}, V_{PB}, V_{MA}, V_{MB}	The value in V of the peak/valley of the analog signal (that is, one-sided reading).
Analog Peak-to-Peak Voltage	V_{PPA}, V_{PPB}	The absolute difference between V_P and V_M of channel A or B.

Digital Output Option

Figure 2: Digital Quadrature Signals A, B, and I Outputs



Digital Parameter Definitions

Term	Parameter	Definition
Count	N	The number of bar and window pairs or counts per revolution (CPR) of the code wheel.
Cycle	C	360 electrical degrees (°e), 1 bar and window pair. One shaft rotation: 360 mechanical degrees, N cycles.
Cycle Error	ΔC	An indication of cycle uniformity. The difference between an observed shaft angle that gives rise to one electrical cycle and the nominal angular increment of 1/N of a revolution.
Pulse Width (Duty) Error	ΔP	The deviation, in electrical degrees, of the pulse width from its ideal value of 180°e.
State	S	The number of electrical degrees between a transition in the output of channel A and the neighboring transition in the output of channel B. There are four states per cycle, each nominally 90°e.
Phase	φ	The number of electrical degrees between the center of the high state of channel A and the center of the high state of channel B. This value is nominally 90°e for quadrature output.
Optical Radius	R_{OP}	The distance from the code wheel's center of rotation to the optical center (O.C.) of the encoder module.
Index Pulse Width	P_0	The number of electrical degrees that an index is high in one cycle.

Absolute Maximum Ratings

Parameter	Symbol	Value
Storage Temperature	T_S	–40°C to 125°C
Operating Temperature	T_A	–40°C to 115°C
Supply Voltage	V_{CC}	7V
ESD Human Body Model	—	4000V
ESD Charge Device Model	—	1000V

NOTE:

- Exposure to absolute maximum rating conditions for extended periods can affect reliability. Stress greater than the absolute maximum rating can cause permanent damage to the device.
- The maximum junction temperature of the PCB must not exceed 125°C.
- Proper operation of the encoder cannot be guaranteed if the maximum ratings are exceeded.
- Remove the Kapton tape only after the SMT reflow process and just before the final assembly. Take precautions to keep the encoder ASIC clean at all times.
- Some particles might be present on the surface of the encoder ASIC. The presence of these particles does not degrade the performance of the encoder.

CAUTION! Take anti-static discharge precautions when handling the encoder to avoid damage, degradation, or both, induced by ESD.

Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit	Notes
Operating Temperature	T_A	–40	25	115	°C	—
Supply Voltage	V_{CC}	2.97	3.3	3.63	V	Ripple < 100 mV_{p-p}
		4.5	5	5.5		
Current	I_{CC}	—	30	65	mA	—
Pin Current (All I/O Outputs)	I	–20	—	20	mA	—
Maximum Output Frequency	F	—	—	200	kHz	At 1X Interpolation
		—	—	400	kHz	At 2X Interpolation
		—	—	800	kHz	At 4X Interpolation
		—	—	1.6	MHz	At 8X Interpolation
		—	—	3.2	MHz	At 16X Interpolation
		—	—	4.0	MHz	At 32X Interpolation
Radial Misalignment	E_R	—	—	±0.2	mm	—
Tangential Misalignment	E_T	—	—	±0.2	mm	—
Tilt Misalignment	E_e	—	—	±2.0	°	—
Code Wheel Gap	G	0.5	1.00	1.5	mm	—
Mylar Code Wheel or Code Strip						As supplied in the HEDS-9830EEVB and HEDS-9830EEVBL evaluation sets
Storage and Operating Temperature	—	–40	25	85	°C	—
Relative Air Humidity	RH	—	—	90	%	Temperature at 60°C

Encoder Pinout

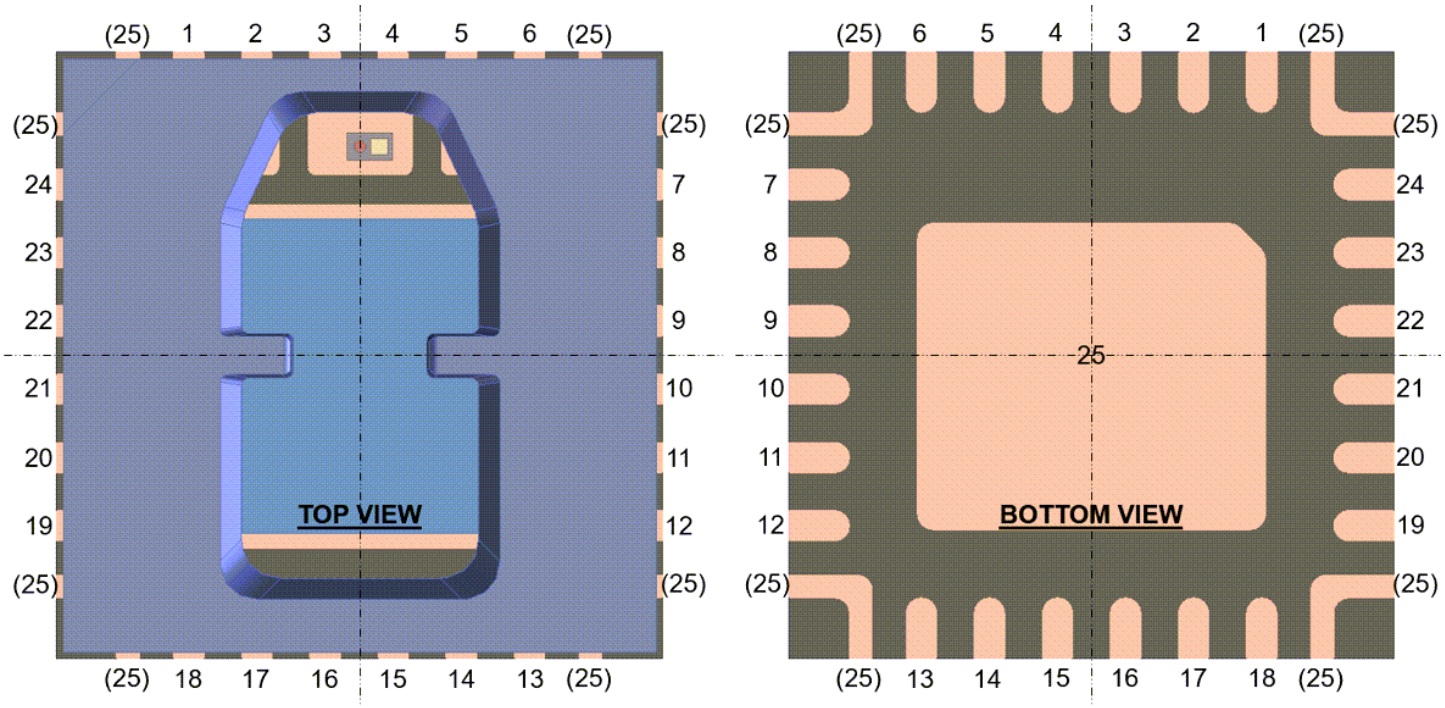


Table 1: AEDR-9830E Pinout

Pin	Name	Function	Pin	Name	Function
1	CH_A / A+	Digital A+ / Analog Sin+	14	N.C.	—
2	No Connect (N.C.)	—	15	N.C.	—
3	LED ANODE	LED Anode	16	N.C.	—
4	LED ANODE	LED Anode	17	N.C.	—
5	LED CATHODE	LED Cathode	18	N.C.	—
6	LED REG	LED Regulation	19	INDEX_SEL	Index control
7	VDDA / VCC	Analog Supply Voltage	20	CH_BB / B–	Digital B– / Analog Cos-
8	VSSA / AGND	Analog Ground	21	CH_B / B+	Digital B+ / Analog Cos+
9	SEL2	Mode Selection 2	22	VSSD / DGND	Digital Ground
10	SEL1	Mode Selection 1	23	VDD	Digital Supply Voltage
11	INDEX_N / I–	Index Output Z– (Digital/Analog)	24	CH_AB / A–	Digital A– / Analog Sin–
12	INDEX_P / I+	Index Output Z+ (Digital/Analog)	25	VSSA	Analog Ground
13	N.C.	—	(25)	NC	—

NOTE:

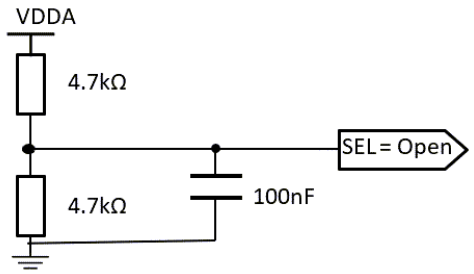
- No connection to all corner pads is indicated as (25).
- Connect pin 8, pin 22, and pin 25 to common ground for all digital or analog mode applications. Pin 25 is the center pad of the package.
- Both pin 7 and pin 23 must be powered during operation.
- Both pin 5 and pin 6 must be connected together.

Select Options – Encoder Built-In Interpolation

SEL 1	SEL 2	IND SEL	Interpolation Factor	Index	Max. Output Frequency	CPR at R_{OP} 7.95 mm	CPR at R_{OP} 11 mm
Open	Open	Low	1X	Gated 90°	200 kHz	625	865
		High		Gated 180°			
		Open		Ungated Raw			
Open	Low	Low	2X	Gated 90°	400 kHz	1,250	1,730
		High		Gated 180°			
		Open		Gated 360°			
High	High	Low	4X	Gated 90°	800 kHz	2,500	3,460
		High		Gated 180°			
		Open		Gated 360°			
Low	Low	Low	8X	Gated 90°	1.6 MHz	5,000	6,920
		High		Gated 180°			
		Open		Gated 360°			
High	Low	Low	16X	Gated 90°	3.2 MHz	10,000	13,840
		High		Gated 180°			
		Open		Gated 360°			
High	Open	Low	32X	Gated 90°	4.0 MHz	20,000	27,680
		High		Gated 180°			
		Open		Gated 360°			
Open	High	N/A	Analog (500 mV_{pp})	Analog	200 kHz	N/A	N/A
Low	High	N/A	Analog 1 V_{pp}	Ungated Digital			
Low	Open	N/A	Analog 1 V_{pp}	Analog			

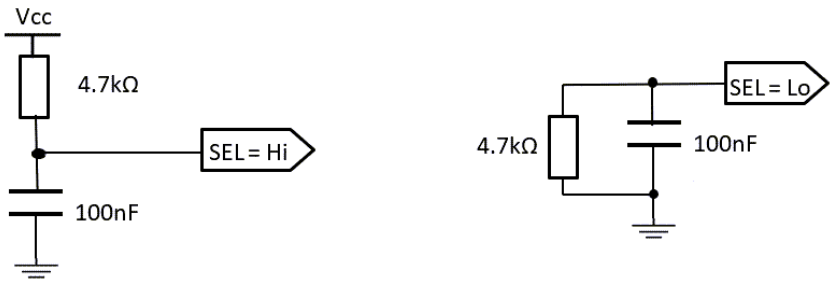
NOTE: Open selection must be connected to middle of a voltage divider circuit.

Figure 3: Example of a Voltage Divider Circuit



NOTE: Recommended to use 2 × 4.7-kΩ resistors (VDDA-GND).

Figure 4: Example of a Hi and Lo Selection Circuit



NOTE: It is recommended to include capacitors at the SEL pins to prevent or eliminate any unwanted disturbance or signal coupling that could potentially impact the mode of AEDR-9830E selection and lead to unwanted behavior of the device.

I/O Pin Considerations

I/O Contention

Do not apply voltage or current to the I/Os of the AEDR-9830E encoder before the encoder is powered up. There are ESD diodes and I/O multiplexing in the device pads, and any undue voltage or current going into the device can partially power up the device and bring it to an unknown state or cause an undue collection of charges prior to a proper power-up. Use proper power sequencing to ensure proper operation of the encoder.

Output Load

The AEDR-9830E encoder is designed for a diverse set of applications, so the encoder provides different modes of functional selection. Careful consideration of the external load is required to prevent unwanted overshoot, ringing, and even instability of the device. Select a proper resistor capacitor load at the output for the mode selected in the application. It is generally not recommended to directly drive a capacitive or inductive load.

Interpolation Factor

The digital interpolation factor in the Select Options – Encoder Built-In Interpolation table can be used in conjunction with the following equations to cater to various rotational speeds (RPM) and counts per revolution (CPR).

RPM = (Count Frequency × 60) / CPR

The CPR (at 1X interpolation) is based on the following equation, which is dependent on the radius of operation (R_{OP}).

CPR = LPI × 2π × R_{OP} (inch) or CPR = LPmm × 2π × R_{OP} (mm)

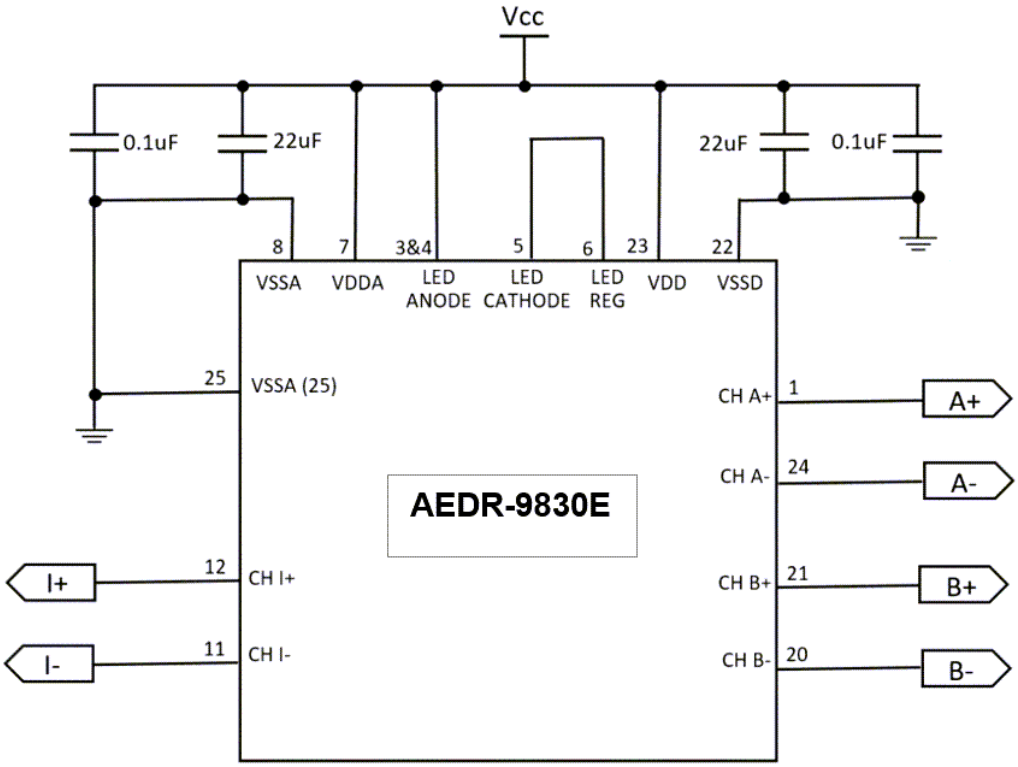
NOTE: LPmm (lines per mm) = LPI / 25.4

Recommended Setup for the Power Supply Pins and General Routing

VDDA, VDD, and the respective grounds (VSSA and VSSD) are to be connected as in Figure 5. Follow these schematic design rules:

- Use a pair of 22-uF and 0.1-uF capacitors as a bypass on VDD and VDDA. Place them in parallel as close as possible to the encoder ASIC package, in between the power and ground pins.
- Avoid routing the INDEX trace in parallel and close to the analog signals to reduce the INDEX signal switching noise from coupling into the analog signal.
- Design separate VDD and VDDA traces.
- Minimize trace or cable length where possible.
- For single-ended applications, do not ground the output from the encoder. Allow the output to float.

Figure 5: AEDR-9830E Schematic Diagram



NOTE:

- Pin 25 is the center pad of the package and is designated as AGND.
- See the table in the Select Options – Encoder Built-In Interpolation section for SEL1X, SEL2X, and IND SEL configurations.

Analog Encoder Characteristics

Parameter	Symbol	Min.	Typ.[a]	Max.	Units
Peak-to-Peak Voltage (Average)	V_{PPA}, V_{PPB}	0.9	1.0	1.1	V
		0.45	0.50	0.55	V
Analog Offset Voltage	$V_{OFFSETA}$, $V_{OFFSETB}$	0.45 V_{CC}	0.5 V_{CC}	0.55 V_{CC}	V
Voltage Reference (Midpoint of Signal V_{pp})	V_{ref}	—	V_{CC} / 2	—	V

a. Typical values represent the average value of encoder performance in Broadcom factory-based setup conditions.

NOTE: Optimal encoder performance depends on the code wheel media and the motor/system setup condition of the individual customer.

Digital Encoder Characteristics

Parameter	Symbol	Dynamic Performance						Units
		Typical[a]						
Interpolation Factor		1X	2X	4X	8X	16X	32X	—
Cycle Error	ΔC	±7	±12	±21	±28	±35	±40	°e
Pulse Width (Duty) Error	ΔP	±6	±13	±14	±18	±25	±35	°e
Phase Error	Δϕ	±3	±7	±7	±9	±9	±15	°e
State Error	ΔS	±6	±8	±11	±12	±14	±25	°e
Index Pulse Width (Gated 90°)	P_O	90	90	90	90	90	90	°e
Index Pulse Width (Gated 180°)	P_O	180	180	180	180	180	180	°e
Index Pulse Width (Gated 360°)	P_O	N/A	360	360	360	360	360	°e
Index Pulse Width (Raw Ungated)	P_O	330	N/A	N/A	N/A	N/A	N/A	°e

a. Typical values represent the average value of encoder performance based on factory setup conditions at the maximum frequency with a metal code wheel.

NOTE:

- Optimal encoder performance depends on the code wheel media and the motor/system setup condition of the individual customer.
- Due to high drive strength and fast slew rate capability, it is recommended to put a series resistor at the Channel AB outputs for the best signal integrity.

Electrical Characteristics

Characteristics are over the recommended operating conditions at 25°C.

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
High Level Output Voltage	V_{OH}	2.4	—	—	V	I_{OH} = –20 mA
Low Level Output Voltage	V_{OL}	—	—	0.4	V	I_{OH} = +20 mA
Output Current per Channel, I_{out}	I_O	—	—	20	mA	—
Rise Time[a]	t_r	—	<50	—	ns	CL ≤ 50 pF
Fall Time[a]	t_f	—	<50	—	ns	

a. Applicable for all digital modes except Index in Analog mode.

Power-Up Behavior

When the AEDR-9830E is powered on, the A, B, and I digital outputs are invalid until after the initial first state of either the Ch A or Ch B signal.

Code Wheel Design Guidelines

- The window tracks are reflective surfaces, and the bar tracks are opaque surfaces; all window and bar tracks are trapezoid.
- The number of Incremental window/bar tracks depends on the CPR; and the Incremental windows/bars have the same width value.
- There is an offset between the Incremental window tracks and the Index window track. There is only one Index window track, and its width is constant.
- The center point to form the Incremental Optical Radius (R_{op}) and the Index R_{op} are two different points, except for 625 CPR.

Figure 6: Code Wheel Design (A)

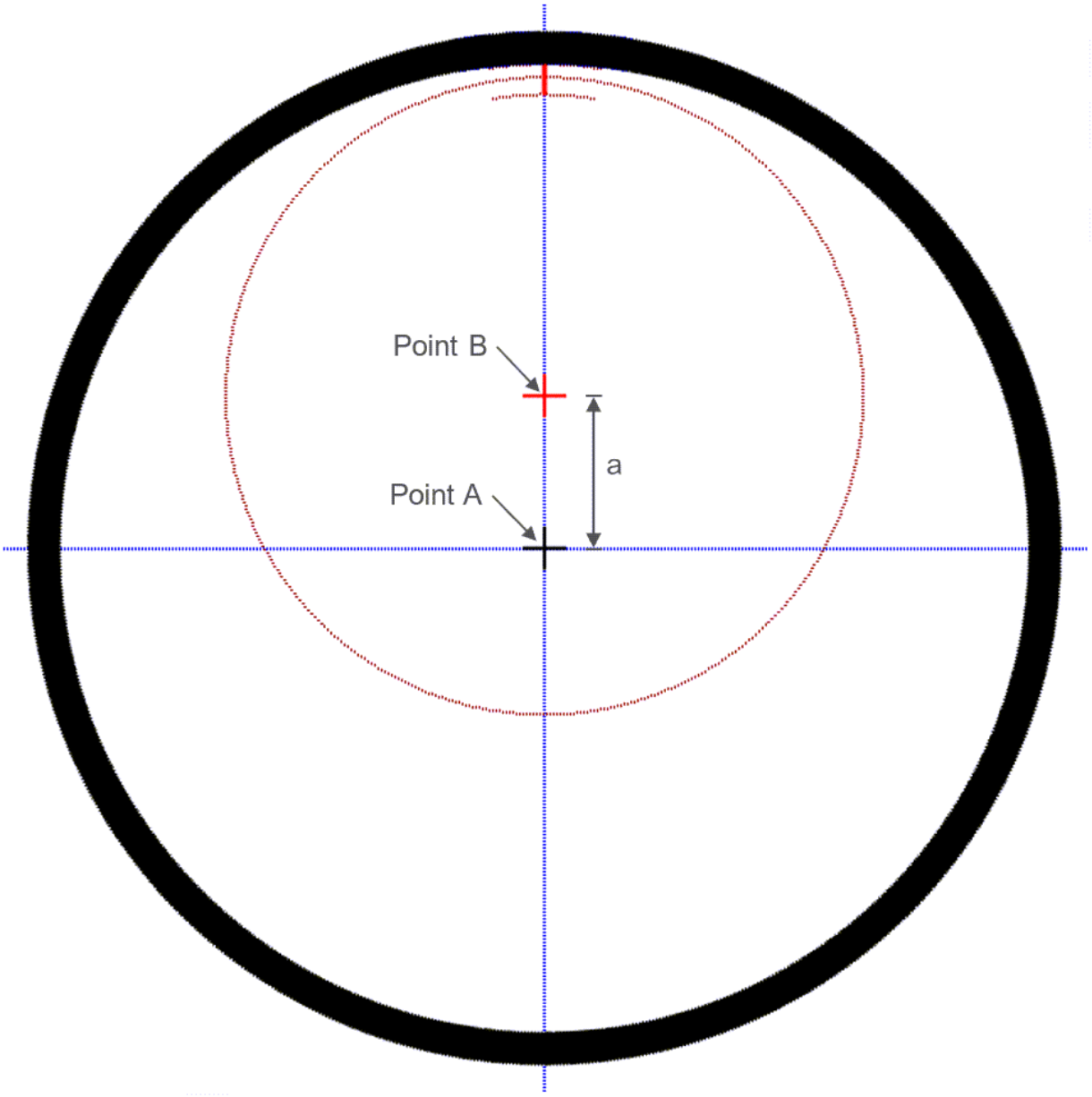
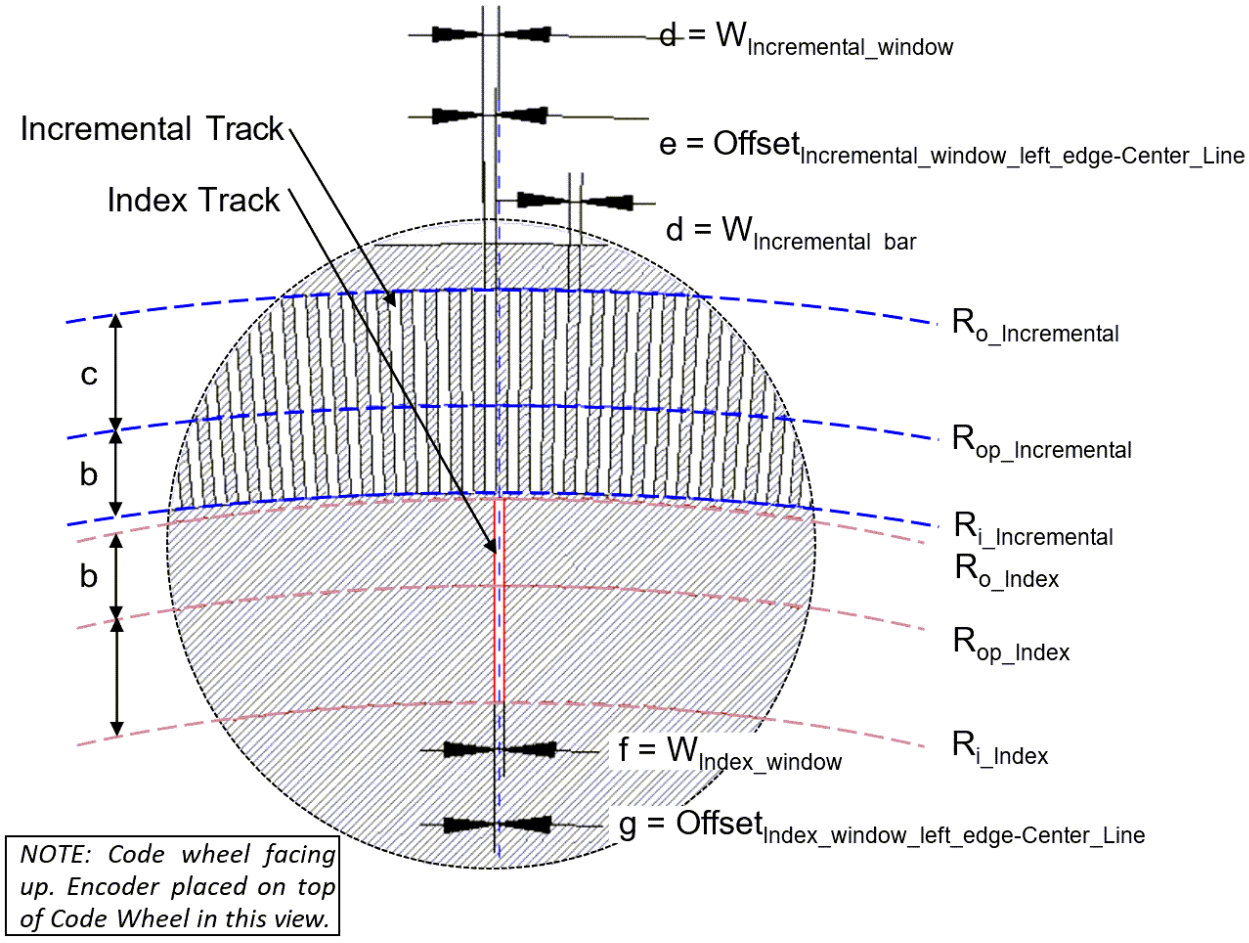


Figure 7: Code Wheel Design (B)



Dimension	Formula	Constant for AEDR-9830E
$R_{op_Incremental}$ (mm)	(25.4 / 318) × (CPR / 2p)	—
R_{op_Index} (mm)	—	R7.3198 from Point B
$R_{o_Incremental}$	$R_{op_Incremental}$ + c	—
$R_{i_Incremental}$	$R_{op_Incremental}$ – b	—
R_{o_Index}	R_{op_Index} + b	—
R_{i_Index}	R_{op_Index} – c	—
a (mm)	$R_{op_Incremental}$ – 7.9452	—
b (mm)	(0.625 – h) / 2	—
c (mm)	$R_{o_Incremental}$ – $R_{op_Incremental}$ or R_{op_Index} – R_{i_Index}	≥0.35
d (°)	(Pitch / 2) or (360 / CPR) / 2	—
e (°)	1.25d	—
f (°)	—	0.288
g (°)	f / 2	0.144
h (mm)	$Ro_{_Index}$ – $R_{i_Incremental}$ at Y-axis	0 ≥ h ≥ 0.05

Code Wheel Design Example

The following text shows a code wheel design for the AEDR-9830E at 625 CPR.

Determine $R_{op_Incremental}$	(25.4 / 318) × (625 / 2p)	= 7.9452 mm
Determine $R_{o_Incremental}$	7.9452 + 0.35	= 8.2952 mm
Determine $R_{i_Incremental}$	7.9452 – (0.625 / 2)	= 7.6327 mm
Determine pitch	360 / 625	= 0.576°
Determine d	0.576 / 2	= 0.288°
Determine e	1.25 × 0.288	= 0.360°

With the preceding information, draw a trapezoid based on Point A (0, 0), and populate 625x at pitch = 0.576°.

Determine a	7.9452 – 7.9452	= 0 mm
R_{op_Index}	—	= 7.3198 mm
R_{o_Index}	7.3198 + (0.625 / 2)	= 7.6323 mm
R_{i_Index}	7.3198 – 0.35	= 6.9698 mm
f		= 0.288°
g	f / 2	= 0.144°

With the preceding information, draw a trapezoid based on Point B (0, 0).

The following text shows a code wheel design for the AEDR-9830E at 1200 CPR.

Determine $R_{op_Incremental}$	(25.4 / 318) × (1200 / 2p)	= 15.2549 mm
Determine $R_{o_Incremental}$	15.2549 + 0.35	= 15.6049 mm
Determine $R_{i_Incremental}$	15.2549 – (0.625 / 2)	= 14.9424 mm
Determine pitch	360 / 1200	= 0.300°
Determine d	0.300 / 2	= 0.150°
Determine e	1.25 × 0.150	= 0.1875°

With the preceding information, draw a trapezoid based on Point A (0, 0), and populate 1200x at pitch = 0.300°.

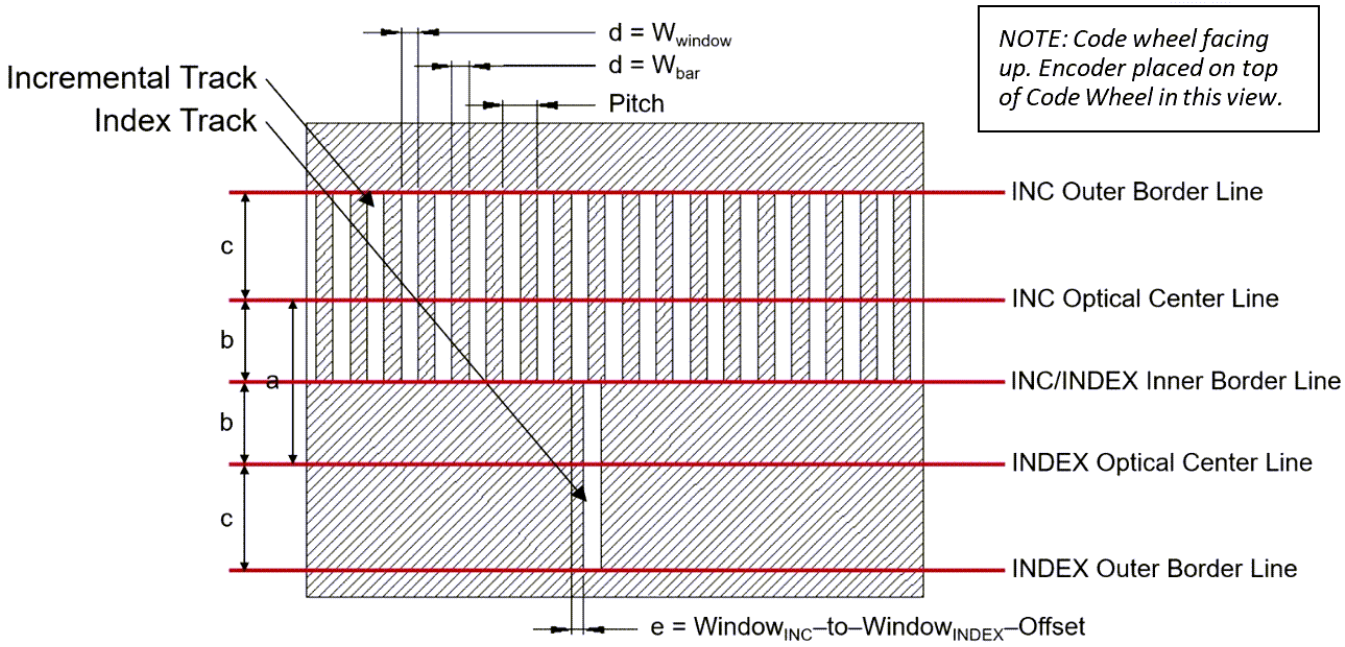
Determine a	15.2549 – 7.9452	= 7.3097 mm
R_{op_Index}	—	= 7.3198 mm
R_{o_Index}	7.3198 + (0.625 / 2)	= 7.6323 mm
R_{i_Index}	7.3198 – 0.35	= 6.9698 mm
f		= 0.288°
g	f / 2	= 0.144°

With the preceding information, draw a trapezoid based on Point B (0, 7.3097).

Code Strip Design Guidelines

- The Incremental/Index window track is a reflective surface, and the Incremental bar track is opaque.
- The window width is denoted by W_{window}, and the bar width is denoted by W_{bar}.
- All windows and bars have the same width value, d.
- There is an offset between the Incremental window track and the Index window track, denoted by e.

Figure 8: Code Strip Design



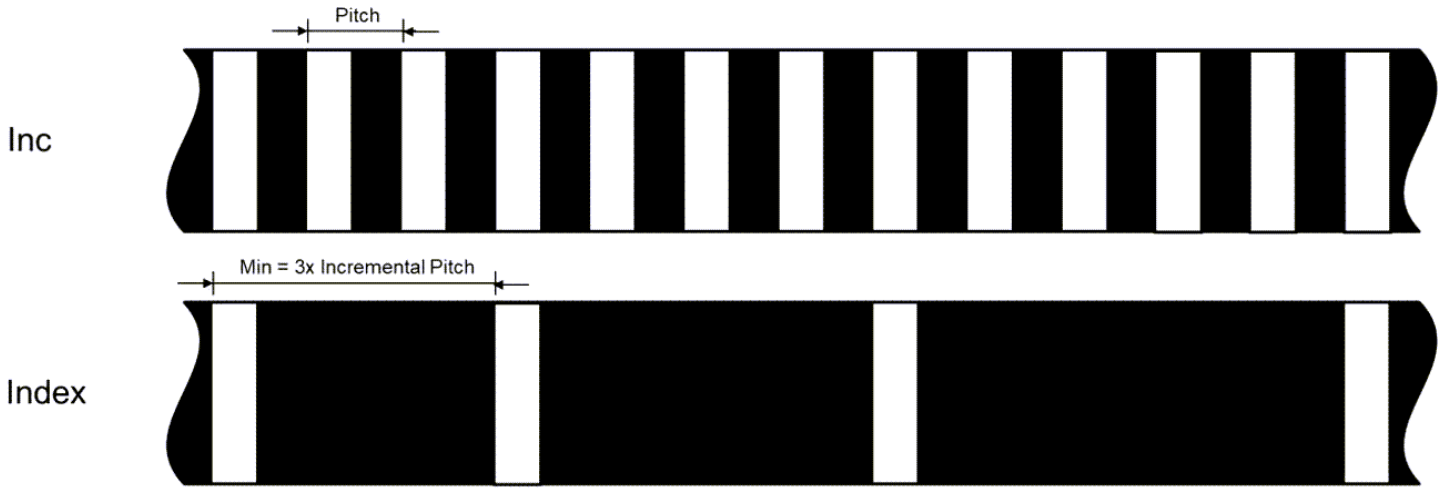
Dimension	Formula	318 LPI
Pitch (mm)	25.4 / LPI	0.080
a (mm)	$R_{OP_INC} – R_{OP_INDEX}$	0.625
b (mm)	$R_{OP_INC} – R_{I_INC}$ or $R_{O_INDEX} – R_{OP_INDEX}$	a / 2
c (mm)	$R_{O_INC} – R_{OP_INC}$ or $R_{OP_INDEX} – R_{I_INDEX}$	0.35
d (mm)	Pitch / 2	0.040
e (mm)	(3 / 4) × d	0.030

Multiple Index Pulse Code Wheel or Strip Design Guideline

For a pseudo absolute encoder application, the multiple Index pulse can be designed into the code wheel or the code strip. The minimum index bar width is 3x the incremental pitch.

The recommended multiple Index pulse design guideline is shown in the following figure.

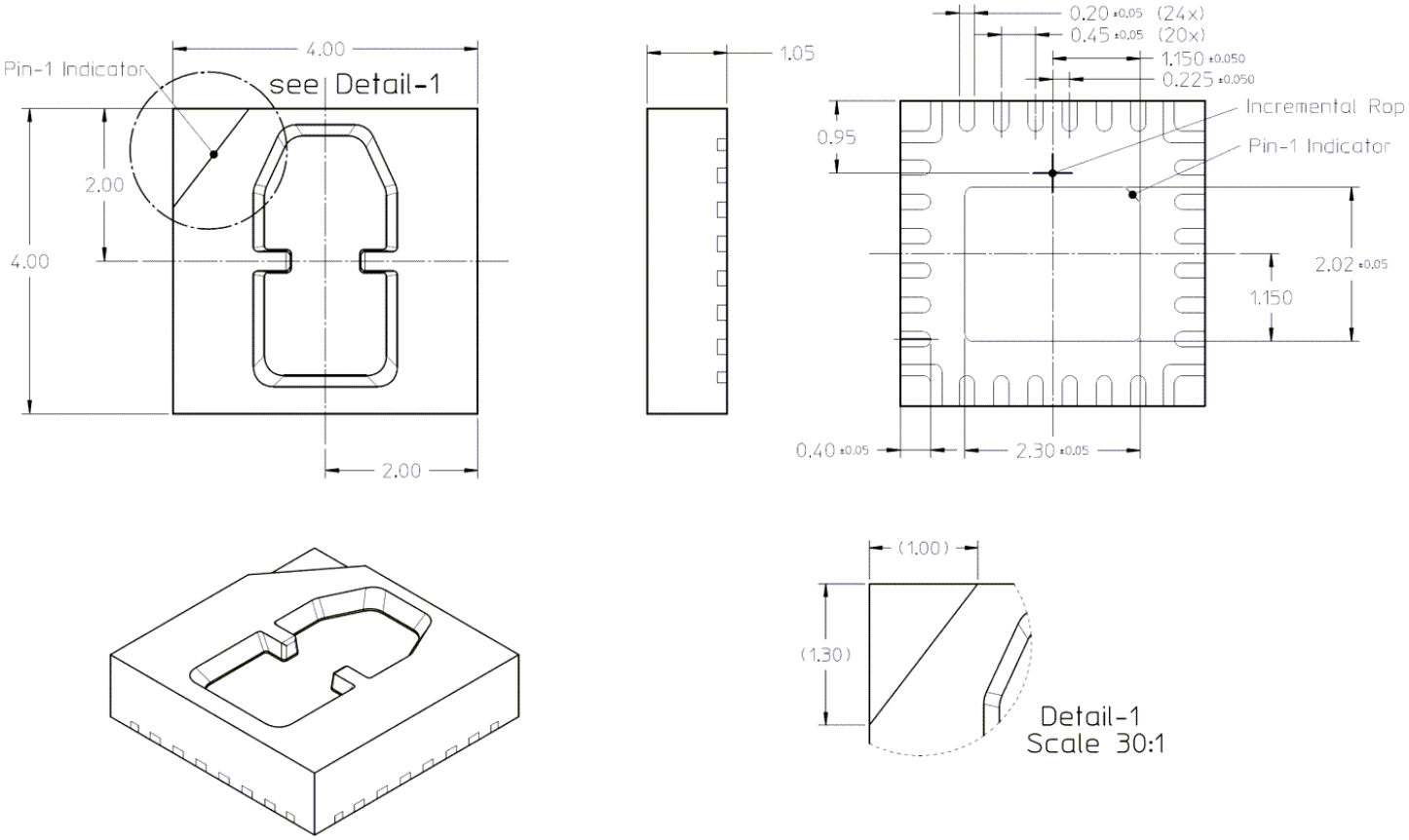
Figure 9: Multiple Index Pulse Design



Example 1		**Example 2**	
LPI	= 318	CPR	= 900
Pitch	= 1inch / 318	Pitch	= 360° / 900
	≈ 80um		= 0.40°
Min Index Pitch	= 3 * 80	Min Index Pitch	= 3 * 0.40
	= 240um		= 1.20°

Package Outline

Figure 10: Package Outline Drawing

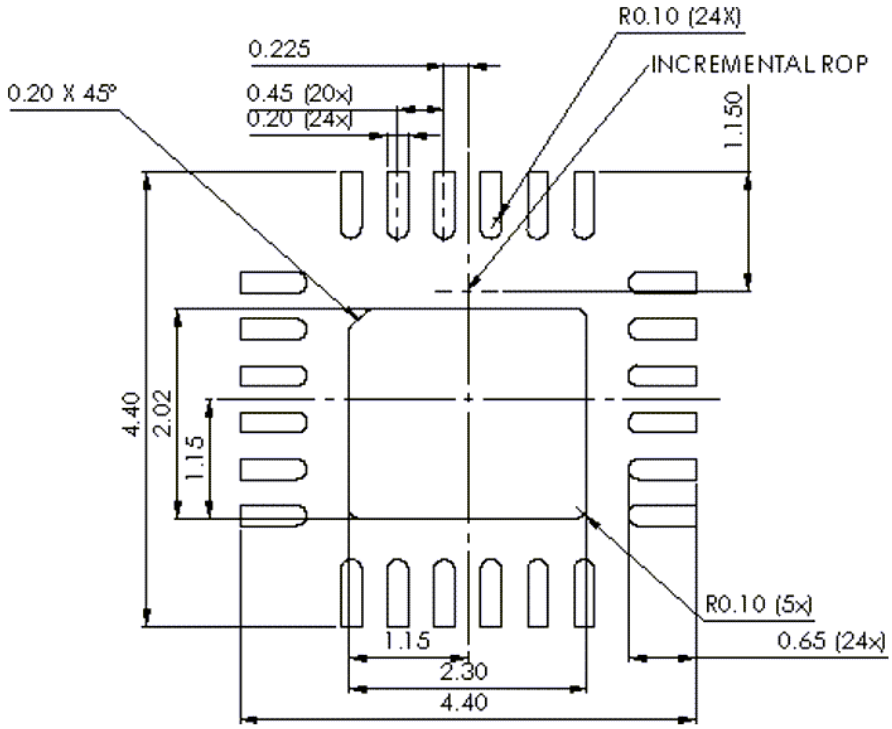


NOTE:

- All dimensions are in millimeters (mm).
- The tolerance is x.xx ±0.15 mm.

Recommended Land Pattern

Figure 11: Recommended Land Pattern



NOTE:

- All dimensions are in millimeters (mm).
- The tolerance is x.xx ±0.05 mm.

Encoder Placement Orientation, Position, and Direction of Movement

The AEDR-9830E is designed with both the emitter and the detector die placed in parallel to the code wheel window/bar orientation. The encoder package is mounted on top, facing down onto the code wheel. When properly aligned, the detector side will be closer to the center of the code wheel than the emitter.

The optical center of the encoder package must be aligned tangential to the code wheel's R_{OP}. The optimal gap setting recommended is 1.00 mm, with the range from 0.50 mm to 1.50 mm.

Channel A leads Channel B when the code wheel rotates counterclockwise, and Channel B leads Channel A when the code wheel rotates clockwise.

Figure 12: Encoder Placement Orientation

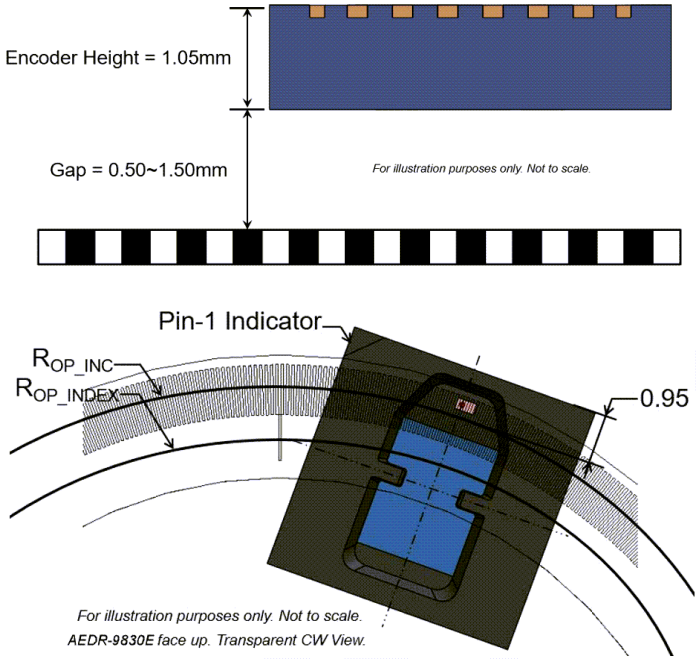
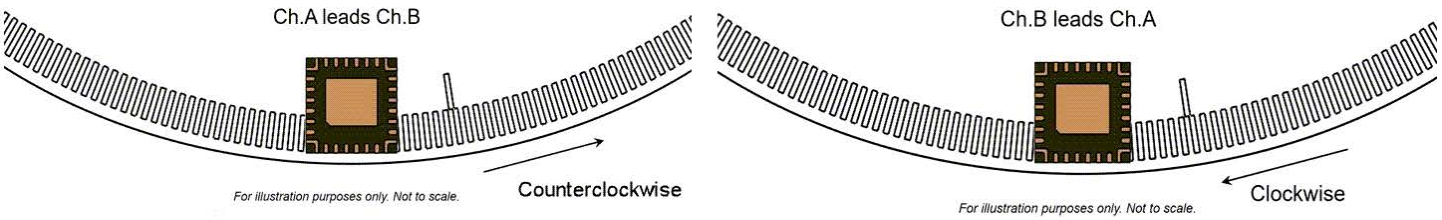


Figure 13: Rotation Direction and Channel Leading Information



Moisture Sensitivity Level

The AEDR-9830E package is qualified to moisture sensitive level 3 (MSL 3). Take precautions when handling this moisture-sensitive product to ensure the reliability of the product.

Storage before use:

- An unopened moisture barrier bag (MBB) can be stored at <40°C/90% RH for 12 months.
- Open the MBB just prior to assembly.

Control after opening the MBB:

- The encoder that will be subjected to reflow solder must be mounted within 168 hours of factory condition <30°C/60% RH.

Control for unfinished reels:

- Store in a sealed MBB with desiccant or desiccators at <5% RH condition.

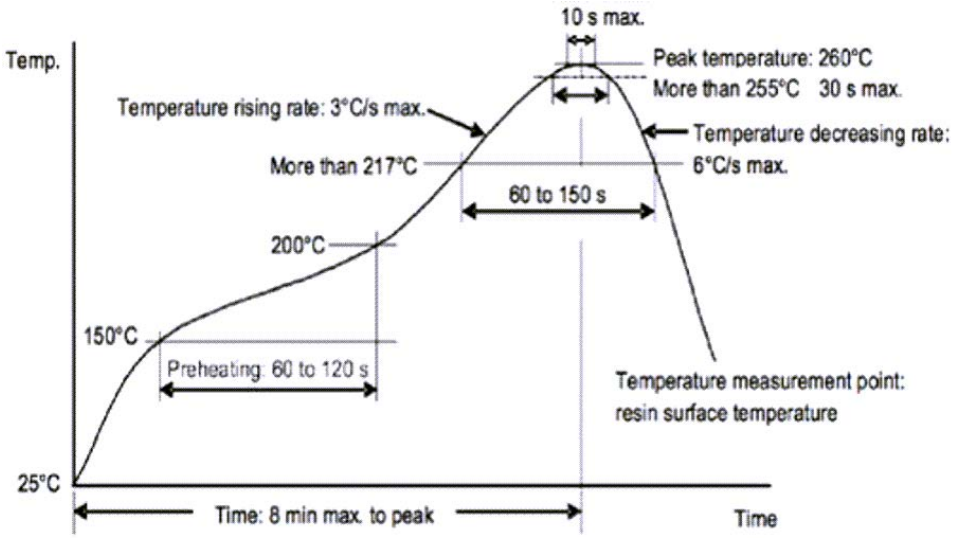
Baking is required under the following conditions:

- The humidity indicator card (HIC) is >10% when read at 23°C ±5°C.
- The encoder floor life exceeded 168 hours.

Recommended baking condition:

- 40°C ±5°C for 22 hours (tape and reel) or 125°C ±10°C for 1 hour (loose units).

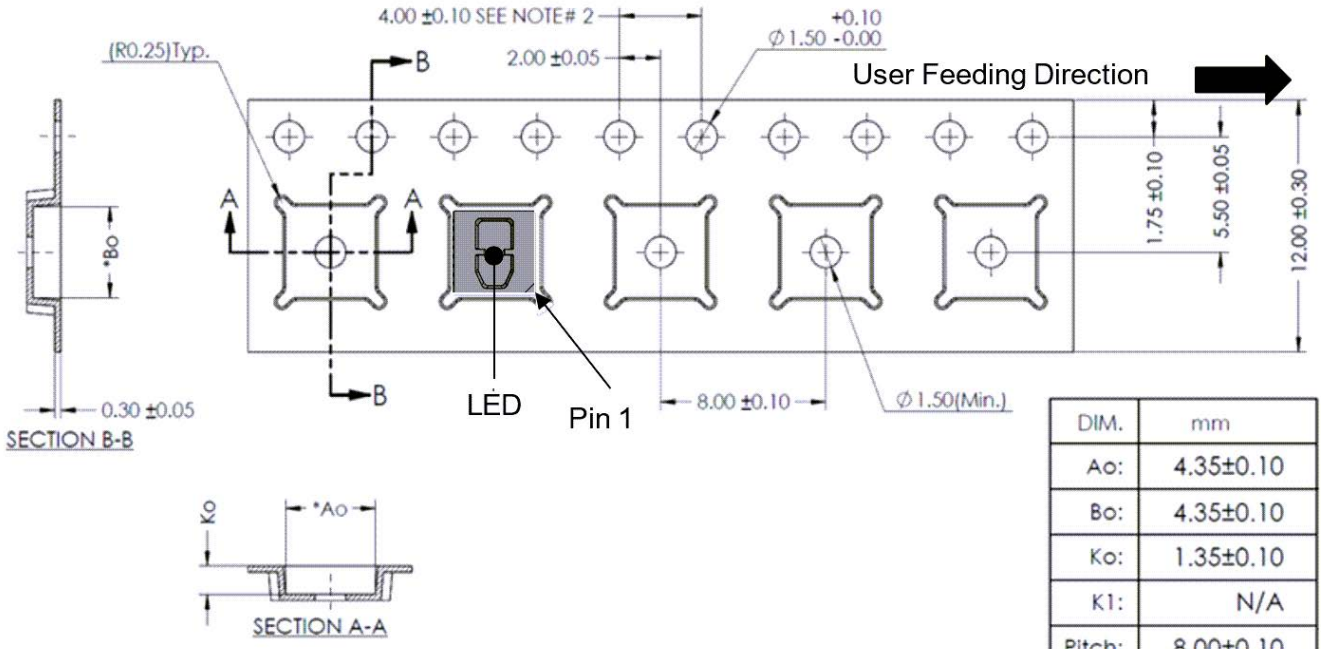
Figure 14: Typical Lead-Free Solder Reflow Profile



CAUTION! Use care when handling the encoder ASIC because it is a sensitive optical device. Remove the protective Kapton tape only after the reflow process and just before final assembly.

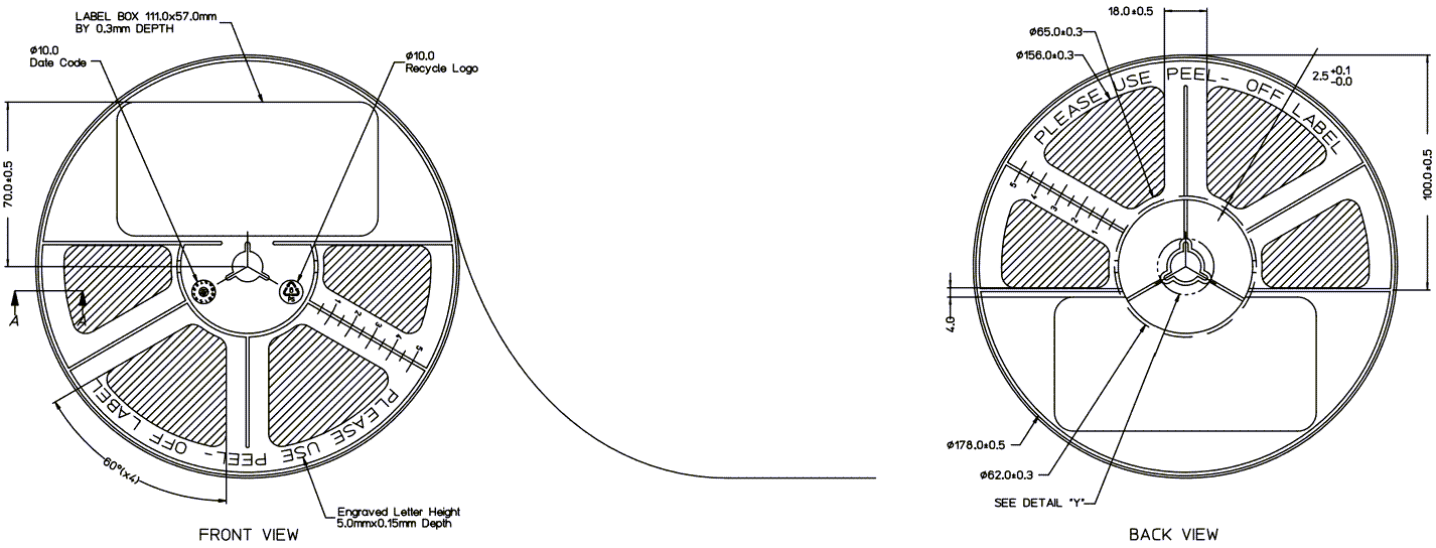
Tape and Reel Information

Figure 15: Tape Dimensions



DIM.	mm
Ao:	4.35±0.10
Bo:	4.35±0.10
Ko:	1.35±0.10
K1:	N/A
Pitch:	8.00±0.10
Width:	12.00±0.30

Figure 16: Reel Dimensions



Ordering Information

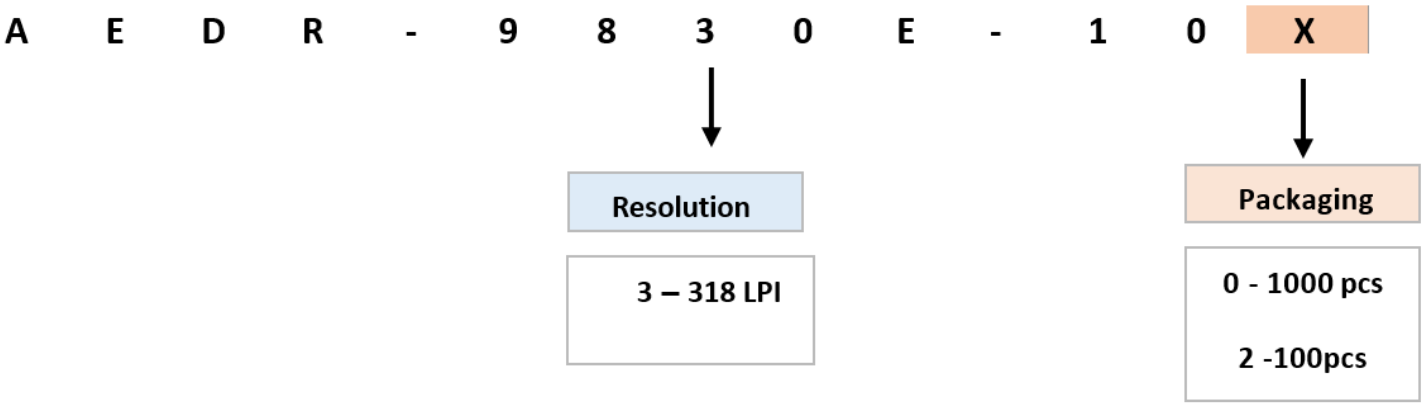


Table 2: Relevant Part Numbers and Accessories Ordering Information

Ordering Information	Type
AEDR-9830E-100	AEDR-9830E, 318-LPI Reflective Encoder, Tape, and Reel, 1000 Pieces
AEDR-9830E-102	AEDR-9830E, 318-LPI Reflective Encoder, Tape, and Reel, 100 Pieces
HEDS-9830EEVB	AEDR-9830E, 318-LPI Evaluation Board with Code Wheel
HEDS-9830EEVBL	AEDR-9830E, 318-LPI Evaluation Board with Code Strip

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